Photovoltaic Thermal Air Collector : A Review

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***Abstract-** In this article relevant literature has been explored to identify photovoltaic thermal air collectors, its typesand classifications on different basis, its general applications in different areas and fields.Solar energy is the most recognized diversified renewable energy from which the productioncan be extracted into electrical and thermal energy. Photovoltaic Thermal (PVT) system is acombinationofphotovoltaic(PV)panelandthermalcollectorwherephotovoltaicpanelconvertsapartofsolarradiationintoelectricity whereasthermalcollectorconvertstheremainingsolarradiationintousefulheat. Suchsystemproduceshigherelectricaloutputalongwiththermal gain whichcan beusedin industrialprocessor spaceheating. Air is made to flow preferably at a constant velocity throughthethermalcollectortocollectsthethermalenergy.Theairflowingthroughtheductalsohelps in keeping the temperature of the photovoltaic panel much lower than the conventional PVTsystem resulting into relatively higher electrical output.*

***KEYWORDS-** Photovoltaic Thermal (PVT), photovoltaic(PV)panel, Building Integrated PVT (BIPVT).*

I. INTRODUCTION

Energyisthekeyroleof all lifekindactivities. Ithas becomeacrucial demandin moderneconomy.Inpractice, nationdevelopmentcanbemeasuredbyitsenergyconsumption.Asthecountrypopulationprogress,theenergyconsumptionincreases.
Energyisalsopredicted to be one of the most challenging and major issues of the world in future time.Forthepastfewdecades,fossilfuelhasbeenprovidingmajorcontribution,whichestimated up to 80% of energy production to the world. This reliable energy provides theserviceandengineeringtothesocietyintermsofimprovinglifestyle,advancedtransportations,cutting-edge communications,vanguardmedicalaidand manymore.
The demand of energy consumed by humankind has been growing significantly over thepast30 years.Itwasrecordedbackon1980–2010thatthetotalprimaryenergyconsumption has massively increased to 75–80%. Due to this overwhelming demand andreportsby numerous oilanalysts,the source of fossilfuelsisgettingdepleted.Theproduction of oil and natural gas is seen to have rapidly increased after a peak in 2015,thereaftertheproductionseemstohavedeclinedanddevelopeddecreasingtrendstowards2050. On the other hand, the rapid energy ingestion also leads to uncontrolled carbondioxide (CO_2) emission as well as pivotal global warming. Fossil fuel contributes to long-term environmental issues such as acid rain and greenhouse effect. These phenomena areverycrucialandbecomeamajorenvironmentalconcerncrisis.Supportedbymeteorologicaldata,theworldisgettingwarmerby0.81C everysixhours.Thiseventuallyintegratesseverenaturalgreenhousegasessuchasnitrousdioxide(NO_2), methane,chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs).
As the year increases, the Earth's temperature and CO_2 emissionaredrastically increased. Worse still, thesecircumstances caused natural disasters such as cataclysmic volcano eruption, earthquake,tsunami,flashfloodandotherdisasterswhichcauseddeathsbythousands.Tomitigatethe climatechangeissues,scientistsarelookingintoalternativeenergyresources.Policymakersareadvocatingdeemphasizingnuclearenergyandfocusingonotheralternatives. This corresponds to the wake of Fukushima double disasters and oil pricevolatility. In addition to that, political crisis unrest in Middle East countries has furtherescalated global oil production. Researchers around the world have been challenged tocome up with environmental-friendly energy resources. In this sense, renewable energy(RE) is a promising candidate to rectify this critical phenomenon that the world is facing.

A. PhotovoltaicThermalSystems

Hybrid PVT Systems simultaneously convert solar radiation to electricity and thermalpower.Performanceandreliabilityandcreditabilitybesidestheyworkonnoiselessenvironment. Efficiency of solar cell will drop when the temperature of it increases. Theefficiencyofthesystemwillloseabout0.3%whencellstemperatureincreasedby1ºC.Aircan be used to cool the surface temperature of the photovoltaic panel. The air will pick upthe surface heat and can be used for domestic of application including drying and otherindustrialprocess heatapplication.
AttractivefeaturesofPVTsystemsare:
1.Itprovidescleanandgreenenergyandnoharmfulgreenhouse gasemission.
2. Solarenergyis supplied byNatureand thus itisfreeand abundant.
3.Operating and maintenance costs for PV panels are considered to be low, almostnegligible,compared to costs of other renewableenergysystems.
4.PVpanelshavenomechanicallymovingparts,exceptincasesof–sun-trackingmechanical bases; consequently, they have far less breakages or require less maintenancethanother renewableenergysystems (e.g. wind turbines)
5.PV panels are totally silent, producing no noise at all; consequently, they are a perfectsolutionforurban areas and for residentialapplications.

II. LITERATURE REVIEW

A. Initialdevelopment on PVT collector: design and performance evaluation

The study of PVT system started in the middle of the 1970s. It was initiated when PVmodule faced a drop in efficiency when the temperature of the surface panel is increased.Martin Wolf was known to be the first to introduce work on flat-plate PV/T liquid-basedsystem [2]. The study was tested for residential heating at Boston, which covered 50m^{2}area. A silicon solar array mounted on a non-concentrating thermal collector is equippedwithlead-acidbatteryandwatertankforelectricityandthermalstorage,respectively.Thefinding showed the combination system is technically practicable and cost effective. Thispioneering study was further developed with mathematical modelling by Florschuetz,which was focused on TRNSYS application. The performance of flat-plate PVT liquidsystem was analysed using the modification of the Hottel– Whillier thermal model basedon cell array efficiency and decreasing cell efficiency with temperature [3-4]. It thenbecame the basis of the PV/T model TYPE 50 in TRNSYS. Among the early work, Kernand Russell also innovated the idea of combining the PV/T system in order to remove theheat on the PV surface so that the efficiency can be improved [5]. The experiment wasperformed using two types of coolant medium separately, which were the medium of airand water. A theoretical approach on PVT systems using conventional thermal collectortechnique was also presented by Hendrie[6]. The mathematical model analysed theperformance of a combined PV/T system for air and liquid based systems. The resultsshowedaverylowefficiencyelectricalperformanceof6.8% comparedtoathermaloutputof 40.4% and 32.9% for air- and liquid-based systems, respectively. During the 1980s,research and development of PV/T system was performed rapidly, there were vigorousstudies covering various methods in order to gain better performance system to meet theapplicationneeds.

PVT system is analysed using monocrystalline, polycrystalline, amorphous or thin filmcells [7]. These variations of solar cells have their own extra features based on theirperformance and also production cost. To capture maximum solar radiation, three classesof concentrator were presented. The first class, which also is of interest by researchers, isflat plate and compound parabolic concentrator (CPC) [8]. Second class consists of linearparabolic reflector and linear Fresnel reflector and the third class consists of 3D Fresnellens [9]. The second and third classes are not chosen for most studies because of thecomplicatedconstructionandmaintenanceissues.Itisalsomainlyfocusedonthedevelopment of building integrated PVT (BIPVT). The type of covered panel also isdiscussed between glazed and unglazed PV panels [10, 11]. It is found that the glazed PVmodules have higher thermal efficiency than unglazed panels. But both types of coveredpanels experienced a very low electrical efficiency due to the additional optical losses.AnotherfieldofstudyexploringthePVTsystemisthetypeof fluidflow.Itisclassifiedasnatural,forcedorlaminarfluidflow[12,13].TheyshowasatisfactoryresultonenhancingairflowonthePVsurface todecreasetemperatureandincreaseelectricalgeneration.

B. DevelopmentinPVTechnology

The physical phenomenon responsible for converting light to electricity-the photovoltaiceffect-wasfirstobservedin1839byaFrenchphysicist,EdmundBecquerel[14].Becquerelnoted a voltage appeared when one of two identical electrodes in a weak conductingsolutionwasilluminated.ThePVeffectwasfirststudied insolids,suchasselenium,inthe1870s.In the 1880s, selenium photovoltaic cells were built that exhibited 1% - 2%efficiency in converting light to electricity. Selenium cells have never become practical asenergy converters because their cost is too high relative to the tiny amount of power theyproduce(at1%efficiency)[15].Amajorstepforwardinsolar-celltechnologycameinthe 1940s and early 1950s when a method (called the Czochralski method) was developed forproducinghighlypurecrystallinesilicon[16].In1954,workatBellTelephoneLaboratories resulted in a silicon photovoltaic cell with a 4% efficiency. Bell Labs soonbettered this to a 6% and then 11% efficiency, heralding an entirely new era of power-producingcells.[17]

A few schemes were tried in the 1950s to use silicon PV cells commercially. Most werefor cells in regions geographically isolated from electric utility lines. But an unexpectedboom in PV technology came from a different quarter. In 1958, the U.S. Vanguard spacesatelliteusedasmall(lessthanone-watt)arrayofcellstopoweritsradio.Thecellsworkedso well that space scientists soon realized the PV could be an effective power source formanyspacemissions.

III. TYPESOFPVTSYSTEMS

Dependinguponvariousconfigurations,thePVTsystemscanbeclassifiedinthreemaincategoriesdescribed as under:

A. Accordingtoflowopasses:

Single pass PVT air collector: A single pass PVT air collector is a combination ofabsorber plate of glass, tedlar or any other material (e.g., Steel), On top of absorber solarcells are attached and glazed after that fluid flow below the absorber plate. This type ofcollectormainlyconsistsofsingleflowofairbelowtheabsorberplate.Theairabsorbstheheatfromtheabsorberplateandreducesthecelltemperatureandimprovestheperformanceof thecollector.

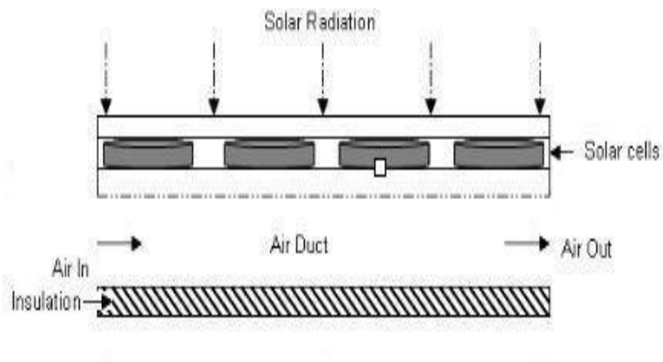

Fig.1.Cross-sectionalview of singlepassPVTaircollector

Double pass PVT air collector:The double pass PVT air collector is very similar tothe single pass PVT air collector. The main difference between them is the number of airflow channels. The top channel consists of a solar absorber and a glass cover. The secondchannel which is located on the bottom of the first channel consists of the same absorberplate(ontop)andinsulatedplate(onbottom).Theairenteringthecollectorisdivided;halfpasses through the upper channel while the remainder flows through the bottom channel.Forbothchannels,theairflowentersthechannelanddirectlyleavesit.UsingadoublepassPVTaircollectorincreasestheheattransferareaandthethermalperformanceofthesystemmaybehigher thanasinglepass PVTair collector modelforthe samemass flowrate.

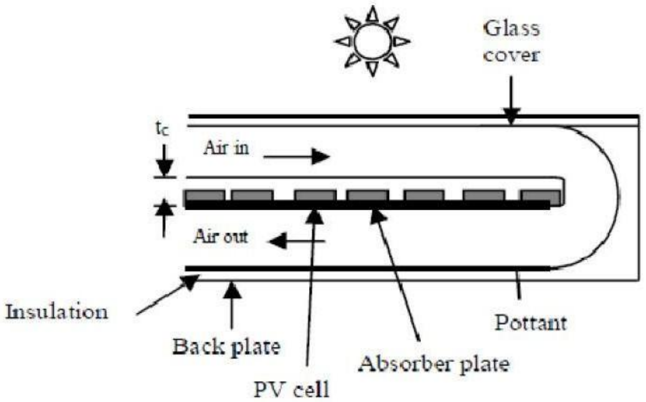

Fig.2Cross-sectionalview of adouble-passPVTaircollector

B. Accordingtocover

Glazed PVT air collector:Glazed systems have a transparent top sheet and insulatedside and back panels to minimize heat loss to ambient air. The absorber plates in modernpanelscanhaveabsorptivityofmorethan93%.Airtypically passesalongthefrontorbackoftheabsorberplatewhilescrubbinghe atdirectly fromit.Heatedaircanthenbedistributed directly for applications such as space heating and drying or may be stored forlateruse.

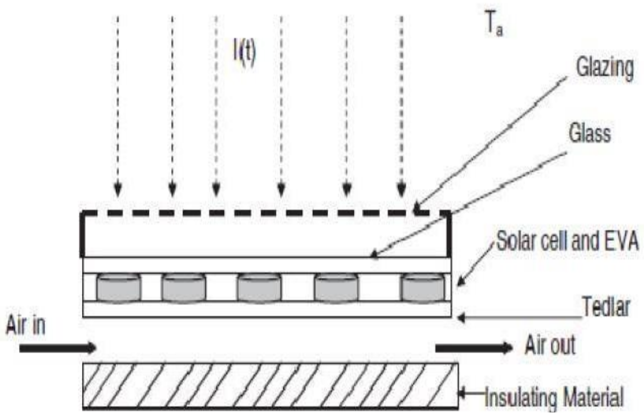

Fig.3 Cross-sectionalviewof GlazedPVTaircollector

Unglazed PVT air collector: Unglazed systems, or transpired air systems, consist ofan absorber plate which air passes across or through as it scrubs heat from the absorber.These systems are typically used for pre-heating make-up air in commercial buildings.Thesetechnologiesare amongthe most efficient.

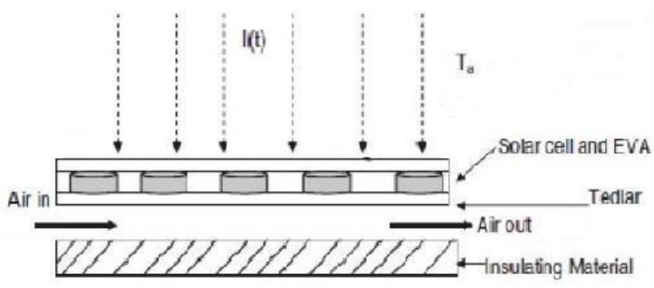

Fig.4Cross-sectionalview ofunglazedPVTaircollector

C. AccordingtoDesignof PVModule:

Glass to glass PVT air collector: As it is shown in Figure, in a two–way hybrid PVTGlass to glass system, solar radiation is absorbed by the solar cell and black surface ofbottominsulationpartitionandheatsthesolarcellandtheinsulator .Thenthermalconvection from both sides of the solar cell and the surface of insulator to the flowing airtakesplace

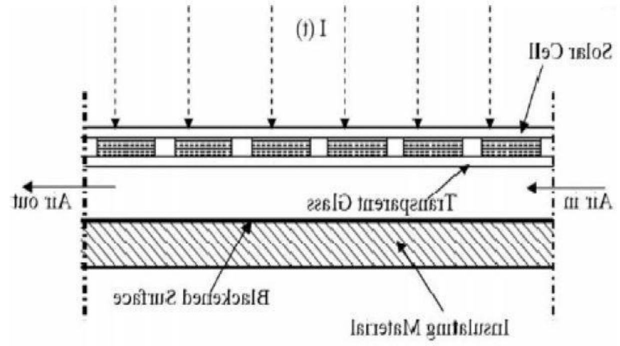

Fig.5Cross-sectionalview of glasstoglassPVTaircollector

GlasstoTedlarPVTAircollector:Glasstotedlarcollectorsolarradiationisabsorbedby the solar cell and tedlar. Then heat is convected from top side of the solar cell andBottomsideof tedlarto theflowingair.

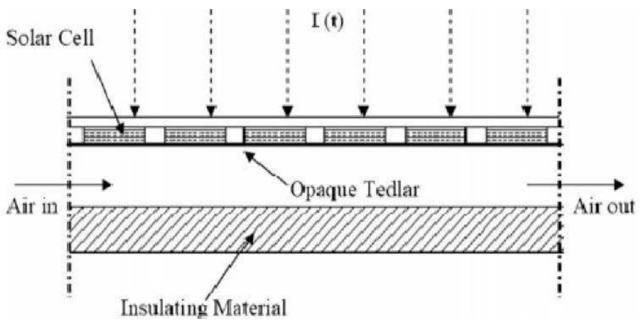

Fig.6Cross-sectionalview of glasstotedlarPVTaircollector

Glass to metal PVT air collector: These type of PV module are not common, Solarcells are attached on the metal plate and then glazed after that collector solar radiation is absorbedbythesolarcellandmetalplate.Thenheatisconvectedfromtopsideofthesolarcellandbottomsideofplatetotheflowingair.In presentthesisweareusingsteelplateasabsorberplate.

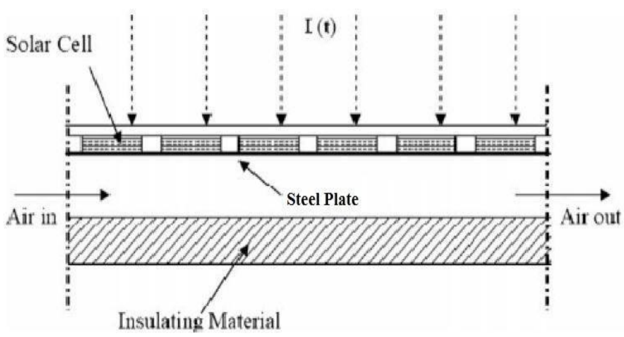

Fig.7Cross-sectional view of glasstosteelPVTaircollector

D. Accordingtotype of fluidflowing:

Gaseous fluid: The fluid which is flowing inside the duct below the absorber plate forPV cooling will remains in a gaseous form throughout the flow e.g. air. Fig. 1.8 clearlyshowsthegaseousfluidtypePVT,inwhichagaseousfluidi.e. airentersthroughinletandleavesthrough outlet,this flowingfluidremains inagaseous formthroughout itsflow.

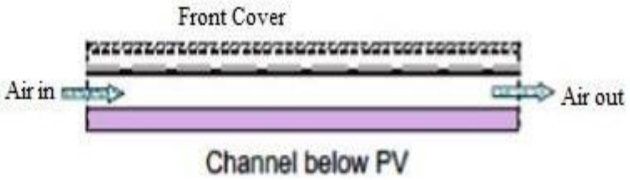

Fig.8Gaseousfluid PVT.

Liquid or refrigerant fluid: The fluid which is flowing inside the duct below theabsorberplateforPVcoolingwillremainsinaliquidstatethrough outtheflowe.g.water,oil or refrigerant. Generally water is used for this purpose due to cost, But when costincrease is not a primary factor then other type cooling media can be used like oils,refrigerantsetc.

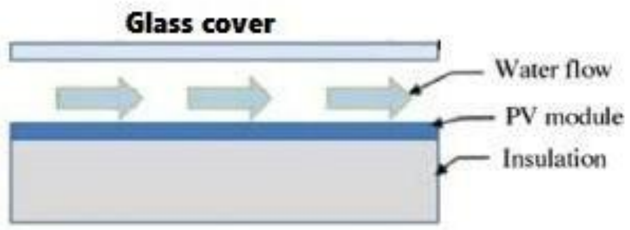

Fig.9LiquidfluidtypePVT

PhasechangematerialtypePVT:Thefluidflowinginsidetheductbel owtheabsorberplate will not remain in a single phase throughout its flow. The fluid flow inside the ductabsorbs heat and changes its phase during the flow. The state of the fluid at inlet and atoutletis different.

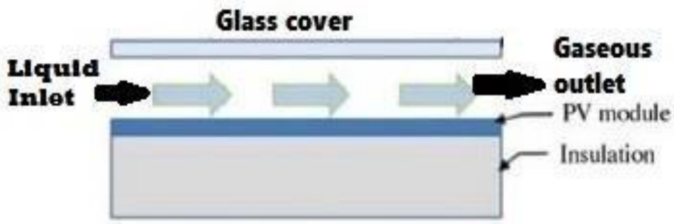

Fig.10 Phasechangefluid typePVT

IV.APPLICATIONSOFPVTAIRCOLLECTORS

A. Power generation and space heating of office and building

Building-integratedphotovoltaics(BIPVs)areapromisingoptionforhousehoLdsinremote,mountainous,andrural areas with no access to the electric grid, as arrays of PV panels are mounted on theroofortheexternalwallsofbuildings.Zeroenergysolarhouses,whereenergyrequiredbythe household appliances is generated by the solar panels at the same premises, could beanother option. In case the energy generated at such houses exceeds the total householdenergyconsumption, thesurplus energycan befedback totheutilitygrid.

B. Crop drying and water pumping in remote areas

The use of solar dryers inagriculturecanprovetobeextremelyefficientduetothelowmanufacturingandoperatingcost. Solar dryers are able to protect grain and fruit, dry faster and more uniformly, andproduce a better quality product than open-air methods. Although current prices for PVpanels make most crop irrigation systems impractical, PV systems are very cost effectivefor remote livestock water supply, pond aeration, and small irrigation systems. Also, PVwater pumping systems may be the most cost-effective water pumping option in locationswherethere arenoexistingpower lines.

C. Remoteelectricitysupply

PVTsystemsconvertsunlightdirectlytoelectricityinmuchefficient way. They can power an electrical appliance directly or store solar energy in abattery.A‘‘remote’’locationcanbeseveralmilesoraslittleas50ft.(15m)fromapowersource.PVTmaybemuchcheaperthaninstalling powerlinesandstep-downtransformersin applications such as electrical fencing and lighting. On an even smaller level, anintegrated micro power generation solution would eliminate the need to plug low powersystemsintotheACmainsforprimarypowerorforbatteryrechargingorreplacementanddisposal.

V.CONCLUSION

Based on the present review, a number of research have been done on PV/T air collectors over the last four decades, exploring aspects such as efficiency enhancements by design development, numerical simulation, prototype design, experimental testing and testing methodologies for PV/T air collectors. Solar energy prove to have an immense constructive impact on environment as a whole contrasting to the fossil fuels consumed on a daily basis. Fossil fuels unfortunately are nearing their extinction and becoming more and more expensive source, resulting in rising electric bills each month. With these issues it is time to capitalize more on developing energy from the sun. Solar photovoltaic technology is employed for directly converting the solar energy to electrical energy by using solar cells.

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